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Effect of Harvest Moisture Content and Ambient Air Drying on Maize Fiber Oil Yield and its Phytosterol Composition

Effect of harvest moisture content and ambient air drying on maize fiber yield, fiber oil content and the phytosterol composition of maize fiber oil were evaluated. Maize was harvested at approximately five different harvest moisture contents (28.0, 23.0, 20.0, 18.0 and 15.0%). Effect of air drying was studied by ambient drying the maize harvested at 28.0% moisture content to 20.0 and 13.0% moisture content. Effect of both harvest moisture content and ambient air drying were significant on all the dependent variables, however, no clear trends were observed. The results suggest that as harvest moisture content goes down the amount of oil extracted from the maize fiber decreases but the concentration of the phytosterols in the maize fiber oil increases proportionally.

Keywords: Phytosterol; Ferulate phytosterol esters; Maize fiber oil; Maize fiber yield

1 Introduction

In the conventional maize wet-milling process, a maize kernel is separated into its individual components. Starch (which constitutes 60–70% of the maize kernel) is the prime product. Other components of the maize kernel, which includes germ (oil), protein and the fiber, are recovered as coproducts. Presently, maize fiber is mixed with heavy steepwater and sometimes with germ meal to produce maize gluten feed which is one of the lowest valued coproducts in a maize wet milling facility. Recent research on maize fiber has shown that it can be used for extraction of maize fiber oil which has three different classes of phytosterol compounds: ferulate phytosterol esters (FPE), free phytosterols (St) and phytosterol fatty acyl esters (St:E)) [1]. In numerous clinical studies phytosterol compounds have been shown to lower serum cholesterol levels and, therefore, have found applications as nutraceutical compounds. Maize fiber oil is different from maize germ oil because maize germ oil contains much lower levels of phytosterols and negligible amounts of FPE.

Research has shown that harvest moisture and drying of maize kernels significantly affects starch yield [2–5], germ yield and its oil content [6]. *Weller* et al. [6], reported a significant drop of 3.2% in germ oil yield with increase in the harvest moisture content from 17.2 to 29.6%. *Freeman* [7] suggested that the low oil recovery in maize harvested at high moisture was probably due to the structural damage or rupture of germ during harvesting.

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Presently, effects of harvest moisture content and ambient drying on yield of maize fiber oil and its phytosterol composition are not known.

Most of the laboratory studies done on maize fiber oil and its composition of phytosterol compounds have been performed using batch steeping processes [8–10]. Batch steeping does not simulate the continuous countercurrent steeping process used by the maize wet-milling industry. In batch steeping there is no fermentation producing lactic acid and, therefore, lactic acid has to be added externally. Moreover, the gradient of decreasing SO_2 concentration and increasing lactic acid concentration in the steepwater during the course of continuous countercurrent steeping does not exist in batch steeping.

The objective of this study was to steep the maize in a continuous countercurrent steeping system to more closely simulate industrial conditions and to evaluate the effects of harvest moisture content and ambient air drying on maize fiber yield, fiber oil content and the phytosterol composition of the oil.

2 Materials and Methods

A yellow dent maize hybrid (3394), grown during the 1998 crop season at the Agricultural Engineering Farm, University of Illinois at Urbana-Champaign, was combine harvested at approximately 28.0, 23.0, 20.0, 18.0 and 15.0% moisture content. Some of the maize harvested at 28% moisture content was ambient air dried to approximately

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20.0 and 13.0% moisture content. Maize samples were hand cleaned to remove broken maize and foreign material, packaged in plastic bags, and stored for a short period of time (approx. 2 to 4 h) at 4 °C until steeped. The whole kernel moisture content of the samples was measured using the 103 °C convection oven method [11].

Maize samples (1,000 ± 0.3 g in each tank) were steeped in a 2,000 ppm SO_2 solution for 24 h at 50 ±2 °C using a laboratory-scale continuous countercurrent system consisting of 16 tanks [12]. The system was started with light steepwater obtained from a local maize wet-milling plant in the Midwest.

Twelve tanks were used to steep maize at any given time and the other four were used as a buffer so that the system could be left unattended for 8 h. The steepwater recycle rate was set at 5.0 mL/s and the draw rate of the light steepwater was 600 mL/kg. The countercurrent steep system was initially run for eight days to allow the steep variables to stabilize as described by *Ping* and *Eckhoff* [13]. After the system reached its steady state (constant profiles of steepwater solids, pH, SO_2 concentration and total acidity), maize samples with five different (15.0, 18.0, 20.0, 23.0 and 28.0%) harvest moisture contents were incorporated individually (at the same harvest moisture content) into the steep system and steeped for 24 h. In addition, two maize samples harvested at 28.0% moisture content, but ambient dried to 20.0 and 13.0% moisture content, also were steeped individually. After steeping, the samples were wet-milled using the 1 kg laboratory maize wet-milling procedure as outlined by *Eckhoff* et al. [l4] to recover the fiber fraction. The collected fiber samples were dried for moisture content determination using the two-stage convection oven procedure [15].

Dried fiber samples were ground to 20 mesh in a Wiley Mill. Ground fiber samples (2 to 4 g) were placed in screw-top vials (55 mL) and 40 mL of hexane was added. The tubes were shaken horizontally for 1 h in a wrist action shaker. After extraction, the hexane extracts were filtered through a Whatman GF/A glass fiber filter (Whatman Laboratory Products, Clifton, NJ) fitted in a Büchner funnel, with gentle vacuum. A part of the hexane extract was removed for HPLC analysis, as previously outlined by *Moreau* et al. [1]. The rest of the solvent sample was dried under nitrogen and heat (approx. 45 °C) (using an N-EVAP Analytical Evaporator, Organomation Associates Inc., Berlin, MA 01503). The dried sample was transferred to 2 dram vials in an 85:15 chloroform-methanol mixture and dried again under nitrogen to measure oil dry weight. The fiber yields, fiber oil recoveries and yield of the three phytosterol compounds (FPE, St and St:E) on dry weight basis were compared for different harvest moisture contents.

Wet-milling of all the samples at different harvest moisture contents were replicated once. Fiber samples from both replicates were analyzed via HPLC at least twice. Results presented are the means of the multiple analyses. All the fiber yields for different treatments and their phytosterols composition (St:E, St and FPE) have been reported on % dry weight basis.

Analysis of variance (ANOVA) and Duncan's multiple range test were used [16] for maize fiber oil and phytosterol compound yields. The level selected to show statistical significance was 5% ($P > 0.05$).

3 Results and Discussion

Statistically significant differences occurred in the fiber yields and fiber oil contents among samples with different harvest moisture contents and between the two ambient air dried maize samples at different moisture contents (Tab. 1). In general, however, no clear correlation related the fiber yield or the fiber oil content with the harvest moisture content. Some significant differences were observed in the composition of the FPE, St and St:E in the maize fiber oil. However, again there was no clear pattern in the phytosterol composition with the change in the harvest moisture content from 28.0 to 15.0%. For the maize samples harvested at 28% moisture content and ambient air dried to 20.0 and 13.0% moisture content, no significant difference occurred in the FPE and the St fractions. However, a significant reduction (almost 50%) in the St:E fraction was observed between the fiber samples dried to 13.0% as compared with the one dried to 20.0% moisture content. The total phytosterol recovery in mg per 100 g maize ranged from 16.15 to 19.08, depending upon the harvest moisture content.

Comparison of the maize sample harvested at 28.0% moisture content to the samples also harvested at 28% moisture content but ambient dried to 20.0 and 13.0% moisture content, showed some interesting results (Tab. 1). The sample that was dried to 20.0% moisture content was not significantly different in fiber yield but was significantly lower in oil (by approximately 0.51%) and FPE (by 1.13 mg/100 g kernels) yields than the sample that was not ambient dried. The sample that was dried to 13.0% moisture content was not significantly different in oil yield but was significantly lower in fiber (by approximately 4.39%) and St:E (by approximately 4.03 mg/100 g kernels) yields than the sample that was not dried. Comparison of the total phytosterols in maize fiber oil for these three samples showed that total phytosterols dropped by 2.12 and 5.04 mg/100 g kernel for samples dried to 20.0% and 13.0% moisture content, respectively, compared to the sample that was not ambient air dried.

Tab. 1. Content and yield of fiber, fiber oil, and ferulate phytosterol esters (FPE), free phytosterols (St) and phytosterol fatty acyl esters (St:E) from corn harvested at five different moisture contents and for corn harvested at 28% moisture content and ambient air dried to 20 and 13% moisture content.

Harvesting/ drying condition	Fiber yield [%]	Oil yield [%]	FPE [mg/100 g kernels]	St [mg/100 g kernels]	St:E [mg/100 g kernels]	Total phytosterol [mg/100 g kernels]
28% M.C.	14.88 BA[a,b]	1.73 A	8.38 A	2.74 AB	6.90 AB	18.02
23% M.C.	12.02 DC	1.64 A	7.72 AB	2.55 B	5.88 B	16.15
20% M.C.	15.34 A	1.15 B	7.83 AB	3.28 A	5.94 B	17.05
18% M.C.	10.85 D	1.84 A	8.35 A	3.14 AB	7.59 A	19.08
15% M.C.	13.19 BC	1.30 B	7.55 AB	3.07 AB	6.29 AB	16.91
28% M.C. Dried to 20% M.C.	14.35 AB	1.22 B	7.25 B	2.83 AB	5.82 B	15.90
28% M.C. Dried to 13% M.C.	10.49 D	1.63 A	7.59 AB	2.52 B	2.87 C	12.98

[a] All yields and the amounts of phytosterol compounds are expressed as percentage of dry solids. Fiber yields are averages of two values and phytosterols yields are averages of four values.
[b] Average yields or the amount of phytosterol compounds followed by the same letter within a column are not significantly different at a 95% confidence level.

The proportions (%, w/w) of all of the three phytosterols (FPE, St and St:E) increased with a decrease in the moisture content of maize from 28.0 to 15.0% (Tab. 2). Comparison of the total weight percent of phytosterols in the maize fiber oil shows that there was approximately a 3.44% increase, as the moisture content decreased from 28.0 to 15.0%. Comparison of all of the three samples harvested at 28.0% moisture content showed that ambient air drying increased the weight percent of individual phytosterols in the maize fiber oil. Depending upon the individual phytosterols, drying increased its weight % in maize fiber oil anywhere from 0.42% to 1.69%. Comparison between the two dried samples showed the biggest change in the weight percent of the St:E in maize fiber oil. The weight of St:E in the maize fiber oil increased by 1.0% for the sample that was dried to 13.0% moisture content, compared to the one that was dried to 20.0% moisture content.

4 Conclusions

Maize harvest moisture content and ambient drying affected the percent oil and oil composition but the effects are not clear. A higher moisture content may result in higher yields of maize fiber oil. However, percent phytosterol content of the oil decreased proportionally with moisture content so that the overall amount of phytosterols per weight of kernels remained about the same.

Tab. 2. Content and weight % of ferulate phytosterol esters (FPE), free phytosterols (St) and phytosterol fatty acyl esters (St:E) in fiber oil and total phytosterol compounds from fiber in corn harvested at five different moisture contents and for corn harvested at 28% moisture content and ambient air dried to 20 and 13% moisture content.

Harvesting drying condition	FPE	St	St:E	Total
	Fiber oil [%, w/w]			
28% M.C.	3.26 ± 10.00[a]	1.06 ± 0.02	2.68 ± 0.00	7.01
23% M.C.	3.95 ± 0.47	1.29 ± 0.06	2.97 ± 0.09	8.21
20% MC.	4.46 ± 0.29	1.81 ± 0.15	3.37 ± 0.03	9.64
18% M.C.	4.22 ± 0.38	1.57 ± 0.03	3.81 ± 0.07	9.60
15% M.C.	4.67 ± 0.69	1.90 ± 0.28	3.88 ± 0.42	10.45
28% MC. Dried to 20% M.C.	4.18 ± 0.51	1.62 ± 0.13	3.34 ± 0.28	9.14
28.0% M.C. Dried to 13% M.C.	4.47 ± 0.33	1.48 ± 0.09	4.37 ± 0.28	10.33

[a] Content and % weight of phytosterol compounds in fiber oil are expressed as percentage dry solids basis and are averages of four values ± standard deviation.

The lower yield but more phytosterol enriched oil at lower moisture content could result from the fracture point of the pericarp being at a different place in the kernel. In other words never dried maize with high moisture may contain more germ contamination. With drier maize, less germ contamination occurs and, therefore the maize fiber oil contains a higher concentration of phytosterol. Results from this study warrant a more detailed study with higher number of replicates at different harvest moisture contents to evaluate the effect of harvest moisture on the phytosterol composition of maize fiber oil.

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